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Inflow conditions and wake effects for wind turbines in forested terrain

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Large rotor modern wind turbines span a considerable part of the atmospheric boundary layer and the inflow conditions are therefore expected to vary during the course of the day and seasons. This is especially true in forested areas in relatively cold climates, where the high roughness of the forest cause correspondingly high levels of turbulence near the surface and boundary layers are often shallow due to prevalent stable conditions and a strong diurnal cycle. This presentation is focused around two sites with tall towers in Sweden. Both towers are well-equipped with a profile of sonic anemometers, from which data were sampled and stored at 20 Hz. Whereas a previous study was focused on describing mean profiles of wind speed and turbulence based on atmospheric stability [1], we here characterize the wind field based on inhomogeneity in the turbulence profile. We present two cases of turbulence inflow conditions: a deep boundary layer case, where the turbulence levels are high over the entire rotor and an inhomogeneous case, where there are sharp gradients of turbulence over the rotor (Fig 1). A subset of data from one of the sites has been used to estimate parameters for the Mann model for the deep-boundary layer and near-neutral case [2]. Using these parameters, we explore a way to modify the generated turbulence field to match observed cases with strong gradients.

Due to the generally high turbulence level associated with forested areas, the turbulent mixing and thereby wake recovery is expected to increase compared to e.g. low turbulent offshore conditions. We investigate wake recovery with a Dynamic Wake Meandering model combined with the aeroelastic code HAWC2 [3,4] for the selected time series.

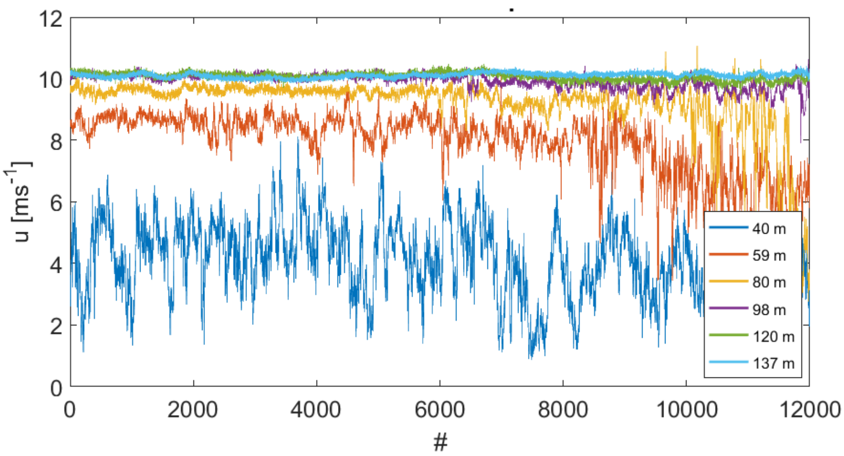

Fig. 1 Time series sampled at 20Hz from example ten-minute period showing large gradients in both turbulence and wind shear.

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1 Arnqvist et al. 2015. Wind Statistics from a forested landscape, Boundary-Layer Meteorol, DOI 10.1007/s10546-015-0016-x

2 Chougule et al 2014, Spectral tensor parameters for wind turbine loadmodeling from forested and agricultural landscapes, DOI 10.1002/we.1709 Wind Energy.

3 Larsen et al. 2008, Wake meandering - a pragmatic approach. Wind Energy, 11, pp. 377–395.

4 Larsen, T.J. et al 2013. Validation of the Dynamic Wake Meander Model for Loads and Power Production in the Egmond aan Zee Wind Farm. Wind Energy, Volume 16, Issue 4, pp. 605–624.